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BROADBAND WIRELESS ACCESS



BWA Standards—Modem Design View

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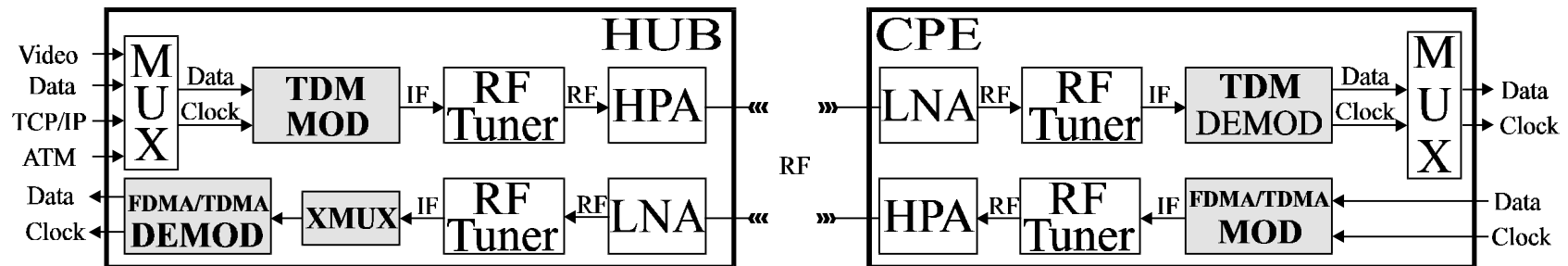
SiCOM WIRELESS SYSTEM SPAN

• HUB-BASED TECHNOLOGY

- High-rate TDM modulator
- FDMA/TDMA demodulator(s)
- Digital channelizer (XMUX) ASICs

• CPE-BASED TECHNOLOGY

- High-rate TDM demodulator
- FDMA/TDMA modulator



“WIRELESS: IT ISN’T WIRED”

- **WHY NOT USE LOW-COST CABLE MODEMS?**
 - Motorola, ADI, Broadcom and others have mature ASIC-based product lines
 - High volumes have greatly-reduced cable modem ASIC cost
- **WIRE AND WIRELESS LINKS ARE *VERY* DIFFERENT**
 - Distinct *link pathologies*
 - **Cable:** Strong multipath; strong SNR; weak CCI; low RF (modest phase noise)
 - **Wireless:** Modest diffuse multipath; low SNR; strong CCI; high RF (high phase noise)
 - Distinct link *cost models*
 - **Cable:** low tuner cost; negligible HPA cost
 - **Wireless:**
 - Tuner: moderate complexity for low baud rates; less complexity at high baud rates
 - HPA: high cost at high baud rates; moderate cost for low baud rates
- **WIRELESS SYSTEMS DEMAND *WIRELESS MODEMS***
 - Select modulation and coding techniques to minimize HPA and tuner cost



THE FUNDAMENTAL CHALLENGE

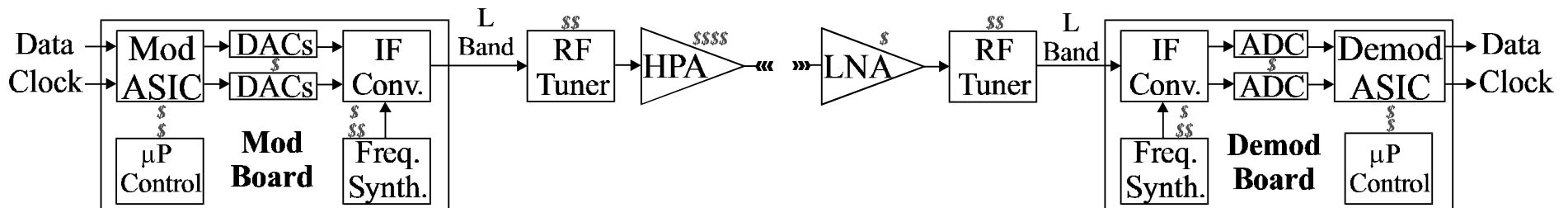
- **“LET’S-GET-RICH” WIRELESS MARKET OPPORTUNITY *ILLUSION***
 - ATM switch suppliers see *their switch* in every CPE
 - Radio suppliers see *their radio* in every CPE
 - Modem suppliers see *their modem* in every CPE
 - A key fact: hundreds of technology approaches will support broadband wireless networking
 - Another key fact: wireless is only one possible solution; we are in for *intense* competition
- **THERE IS ONLY ONE *REAL* MARKET OPPORTUNITY**
 - Satisfy **CPE-to-fiber *broadband connectivity*** needs at the **lowest cost**
- **SELECT THE WIRELESS ARCHITECTURE BASED ON COST**
 - Competition will not tolerate a low-cost modem requiring an expensive architecture
 - The broadband wireless architecture itself must reflect minimum-cost constraints
- **OTHERWISE:**
 - Wired architectures will displace wireless
 - Wireless isn’t “wired”

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WIRELESS LINK COST MODEL

• SYSTEM COST MUST DRIVE MODEM DESIGN

- What can you do with modulation/coding to reduce tuner cost?
- What can you do with modulation/coding to reduce HPA cost?
- Can you develop an architecture to minimize system cost?



MILLIMETER-WAVE MODEMS

- **MILLIMETER -WAVE PATHOLOGIES**
 - Modest link distortion and interference
 - *Severe cost pressure: tuner phase noise* at frequencies >10 GHz
 - *Severe cost pressure: HPA peak-power* expense
- **MODEM MUST:**
 - Be ideally matched to millimeter-wave propagation
 - Be highly insensitive to tuner phase noise at high baud rates
 - Use waveforms allowing HPA operation *AT SATURATION (1 dB compression)*

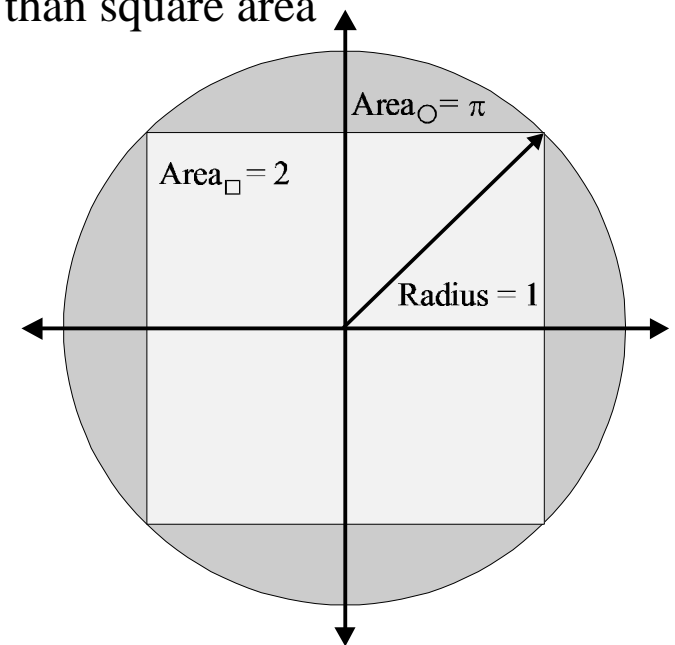
PTM CHALLENGE: WIRELESS PHASE SNAPS/CLICKS

- **WIRELESS LINKS LOSE PHASE SYNCHRONIZATION**
 - Carrier phase sync is lost due to phase snaps, phase clicks, or loop cycle slips
 - Without phase sync, the data stream bit error rate (BER) = 50%
 - Even when phase sync is re-established, the decoder may not function correctly
 - In 8PSK, a non-rotationally-invariant (**NRI**) PTCM only works at **1 of 8** phase lock states
 - Cycling through the multiple lock states increases error burst length by millions of bits
- **SOLUTION: USE FRI PTCM for 8PSK and HIGHER**
 - FRI (Fully-Rotationally-Invariant) PTCM Can Reduce PTM System Cost
 - Expensive LNBS are not required to avoid phase snaps
 - Expensive VCOs are not required to minimize cycle slips
- **FRI PTCM CAN FLYWHEEL RIGHT THRU SLIPS!**
 - *All* phase-lock points result in *proper decoder operation*
 - Convolutional interleaving distributes the error burst transient
 - Reed-Solomon decoding digests the error bytes

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SiQAM FOR POWER-EFFICIENCY

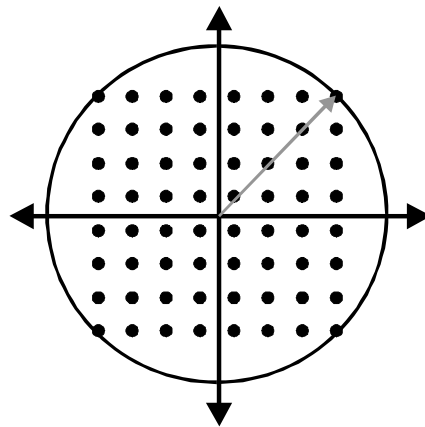
- **BER IS DRIVEN BY NEAREST TWO POINTS**
 - **Optimal constellation** maximizes minimum inter-point distance
- **HPA LIMITS AVAILABLE AREA**
 - Same peak power: circular area is **1.97 dB** greater than square area
- **OBJECTIVE:**
 - Determine optimal polar constellation/coding
 - Recover *potential 2 dB SNR improvement*
- **CONSTRAINT: PTCM compatibility**
 - Retain code rate flexibility



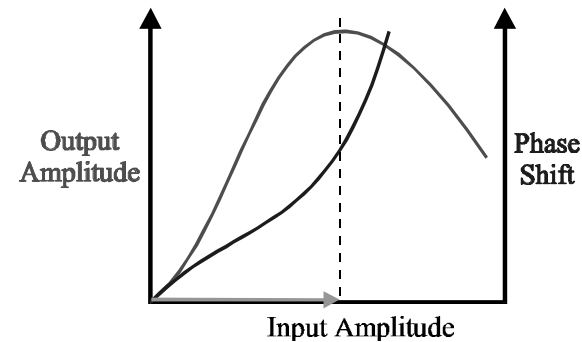
BW- & POWER-EFFICIENCY

• MODEMS NEED NEW DESIGN CONCEPTS

- Bandwidth constraints: high-order modulations
- HPA constraints: MAPSK modulations
- SNR constraints: SiQAM coding
- Cost constraints: ASIC implementations



Conventional 64QAM



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PTM CHALLENGE: CO-CHANNEL INTERFERENCE

- **1 FREQUENCY BAND; 2 POLARIZATIONS**
 - **Worst-case forward link:** $H_{1(h)}$, $H_{1(v)}$, $H_{2(v)}$, and $H_{2(h)}$ received by $C_{1(h)}$
 - **Worst-case return link:** $C_{3(h)}$, $C_{1(h)}$, $C_{2(v)}$, and $C_{4(v)}$ received by $H_{2(h)}$
 - Assume: 18 dB polarization discrimination

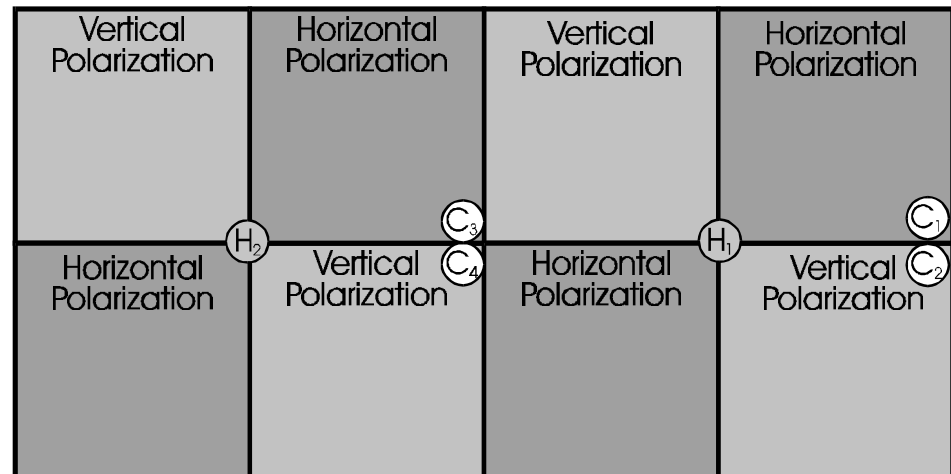
- **FORWARD LINK**

- $SIR < 8.9$ dB

- **RETURN LINK**

- $SIR < 8.9$ dB

dB	
-9.540	0.111
-27.540	0.002
-18.000	0.016
Sum	0.129
-8.901	



PTM CHALLENGE: LINK DISTORTION

- **LMDS LINK DISTORTION MECHANISMS**
 - **Non-ideal components**
 - HPA introduces nonlinear distortion, worsening as backoff from saturation is reduced
 - Low-cost CPE constraint results in relatively high VSWR and other in-band distortion
 - **Multipath**
 - Multipath is rarely discrete at LMDS frequencies; antenna placement handles rare problem
 - Multipath is primarily diffuse, with long delay span
- **CHALLENGES:**
 - Permit HPA to operate near saturation without link degradation
 - Eliminate spectral regrowth associated with nonlinear amplification
 - Eliminate BER degradation associated with nonlinear amplification
 - Eliminate multipath distortion without requiring complex equalization

PTM CHALLENGE: ROBUST HIGH-ORDER LINKS

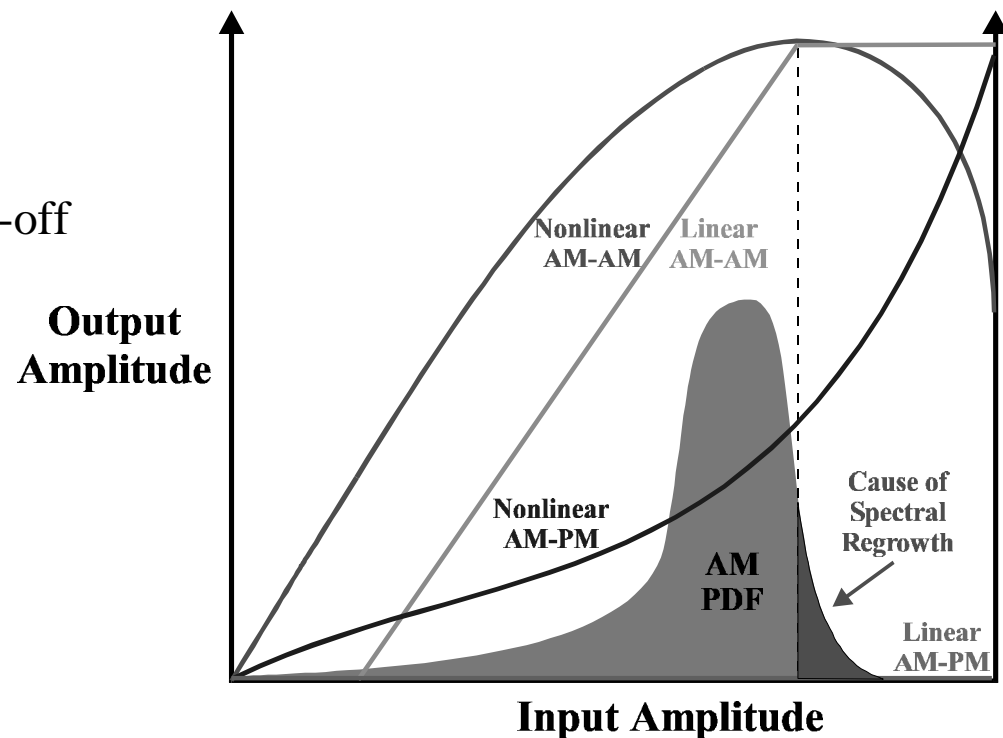
- **LMDS BACKHAUL LINKS NEED EXPENSIVE HPAs**
 - PTM backhaul links require high-order bandwidth-efficient modulations
 - Higher-order modulations require backoff from HPA saturation levels
 - Lower values of excess bandwidth (α) require higher values of backoff
 - HPA cost rises sharply as required peak power levels increase
- **CHALLENGE:**
 - Eliminate the need for HPA backoff on high-order-modulation signals
 - Avoid increasing sensitivity to channel distortion

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PTM CHALLENGE: HPA SPECTRAL REGROWTH

- **EVEN LINEARIZED HPAs REQUIRE LARGE BACKOFF**
 - Bandwidth-efficient (Nyquist) signaling requires low “excess bandwidth” values
 - Low “excess bandwidth” (α) values create large signal amplitude excursions
 - Whenever amplitude exceeds HPA linear region, spectral regrowth occurs

- **CHALLENGE:**
 - Eliminate spectral regrowth
 - Minimize required HPA back-off



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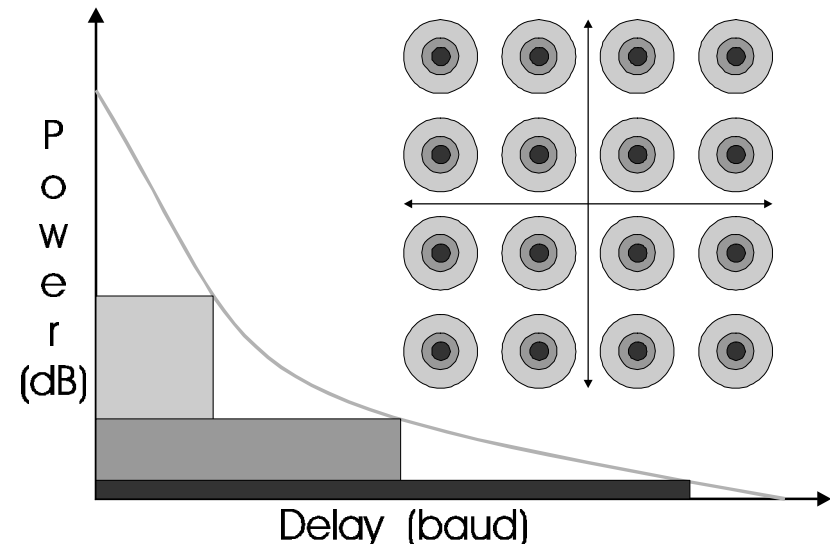
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CONSTRAINED-ENVELOPE ROOT-NYQUIST (CERN) MODULATION

- **LOW- α ROOT-NYQUIST SIGNALS:**
 - *Universal standard* for nearly all modern wireless transmission
 - Require many dB of HPA ‘backoff’
 - Require *expensive HPAs*
 - Severely aggravate PTM’s co-channel interference problem
- **Challenge: Find a way to use LOW- α pulse shaping with reduced HPA backoff**

ADAPTIVE EQUALIZATION

- **UNIQUE JOINT FEC/EQUALIZATION DESIGN**
 - Adaptive equalization for first-order distortion effects
 - Forward error correction to eliminate residual distortion impact
- **PROPER CODE DESIGN CUTS EQUALIZER LENGTH**
 - Equalization must reduce distortion to level consistent with FEC
 - Stronger coding can greatly reduce equalizer length requirements
 - Interleaver length impact:
 - Interleaver must be “matched” to channel



SUMMARY / CONCLUSION

- **“LOW-COST” MUST APPLY TO THE SYSTEM ARCHITECTURE, NOT JUST THE MODEM CHIPS**
 - The modem design should reduce cost in the rest of the system
- **MODEM DESIGN MUST MATCH THE PROBLEM**
 - Phase noise at high frequencies
 - Link distortion (HPA-induced distortion and channel distortion)
 - Bandwidth- and power-efficient modulation/coding and waveforms
 - Co-channel interference
- **APPLY A SYSTEM ENGINEERING APPROACH TO MINIMIZE OVERALL SYSTEM COST THROUGH INTEGRATED MODULATION, CODING, EQUALIZATION, AND WAVEFORM DESIGN**